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ABUNDANCE OF THE GEORGE LAKE  
NORTHERN PIKE POPULATION IN 1987  
AND VARIOUS LIFE HISTORY FEATURES  
OF THE POPULATION SINCE 1972<sup>1</sup>

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# ABSTRACT

The northern pike *Esox lucius* population in George Lake, east of Delta Junction, Alaska, was twice sampled in June 1987, with seines. Abundance of northern pike over 299 millimeters fork length was estimated to be 17,662 fish (standard error of the estimate was 2,105 fish). Density of northern pike over 299 millimeters fork length was estimated to be 9.69 fish per hectare, whereas, density of northern pike larger than 449 millimeters fork length was estimated to be 4.66 fish per hectare. Female northern pike were more abundant than males in the larger length classes. Length frequency plots showed peak abundance of northern pike in the eight length classes (25 millimeters each) between 300 and 524 millimeters of fork length. No trophy size northern pike were found in George Lake. Stock size fish represented 74 percent of the population. The oldest male and female northern pike were 12 years old. The age 4 cohort was most abundant, representing 31 percent of the estimated abundance of northern pike over 299 millimeters fork length. Length-at-age relationships for male and female northern pike in 1987 were significantly different, with females being larger at age. Although variation in mean length-at-age statistics for 3, 4, 5, 6, 7, and 8 year old northern pike sampled from 1972 through 1987 was noted, no consistent trends were apparent. Male northern pike grew an average of 33 millimeters per year based upon 1987 length-at-age analysis and 53 millimeters per year based upon lengths of fish tagged in 1986 and recaptured in 1987. Female northern pike grew an average of 45 millimeters per year based upon 1987 length-at-age analysis and 54 millimeters per year based upon lengths of fish tagged in 1986 and recaptured in 1987. Recent annual harvests of northern pike in George Lake by the recreational fishery may not be sustainable.

KEY WORDS: Northern pike, *Esox lucius*, George Lake, Alaska, abundance, mark-recapture, growth, length-weight, length-at-age, sex ratios.

## INTRODUCTION

Northern pike *Esox lucius* have become increasingly popular with interior Alaska anglers in recent years. Next to Arctic grayling *Thymallus arcticus*, northern pike are the most sought after indigenous sport fish species in interior Alaska (Holmes 1987). Harvests of northern pike in interior Alaska averaged about 14,500 fish between 1977 and 1984 with more recent harvests being about 15,500 fish (Mills 1986). Interior Alaska accounts for 75% to 90% of the Alaskan northern pike harvest on an annual basis and Tanana River Drainage waters alone account for about 65% of the harvest. Minto Flats, Volkmar Lake, and George Lake are the three most popular northern pike fishing areas in the Tanana River Drainage and Minto Flats and George Lake support the two largest northern pike fisheries in Alaska.

Periodic stock assessment and creel census studies of northern pike resources and fisheries in the Tanana River Drainage were conducted from 1971-1984 (Peckham 1972-1985). Research at Volkmar Lake in 1985 (Peckham 1986) provided the first estimate of northern pike abundance in Alaska along with life history information for this population. Research conducted in interior Alaskan lakes during 1986 provided additional estimates of abundance along with catch per unit of effort statistics, catchability coefficients, and life history information for northern pike in Volkmar, T, and George Lakes (Peckham and Bernard 1987). The research program in Volkmar, T, and George Lakes was continued in 1987, and a study of northern pike in Minto Flats began.

This report summarizes research conducted in 1987 concerning abundance and life history of northern pike in George Lake. This report also summarizes various information collected intermittently from George Lake since 1972.

### Study Area

George Lake (63°47'N, 144°31'W) is a semi-remote lake (1,823 ha) located approximately 8 km northeast of the Tanana River and the Alaska Highway about 45 km southeast of the town of Delta Junction (Figure 1). The lake is accessible during the open water season by boat via the Tanana River and George Creek or by float equipped aircraft. Although George Creek is navigable by boat, it is shallow, requiring a boat powered with a jet unit or an outboard equipped with a lift device. Snow machines and ski equipped aircraft provide a means of access during the winter.

George Lake lies at an elevation of 389 m and has a maximum depth of 11.0 m. The lake has one major inlet, six smaller inlets, and an outlet (George Creek) that flows into the Tanana River. George Lake is usually ice free from early June through mid-October. Near-shore waters are shallow. These shallow areas support extensive beds of aquatic vegetation, providing northern pike with spawning substrate as well as rearing habitat for juvenile and adult fish.

Several recreational cabins are located along the lake shore. These cabins, along with various camping sites, are used by recreational fishermen attracted to George Lake for open water angling for northern pike. In addition to summer angling, there is a winter spear and hook and line sport fishery for northern pike.

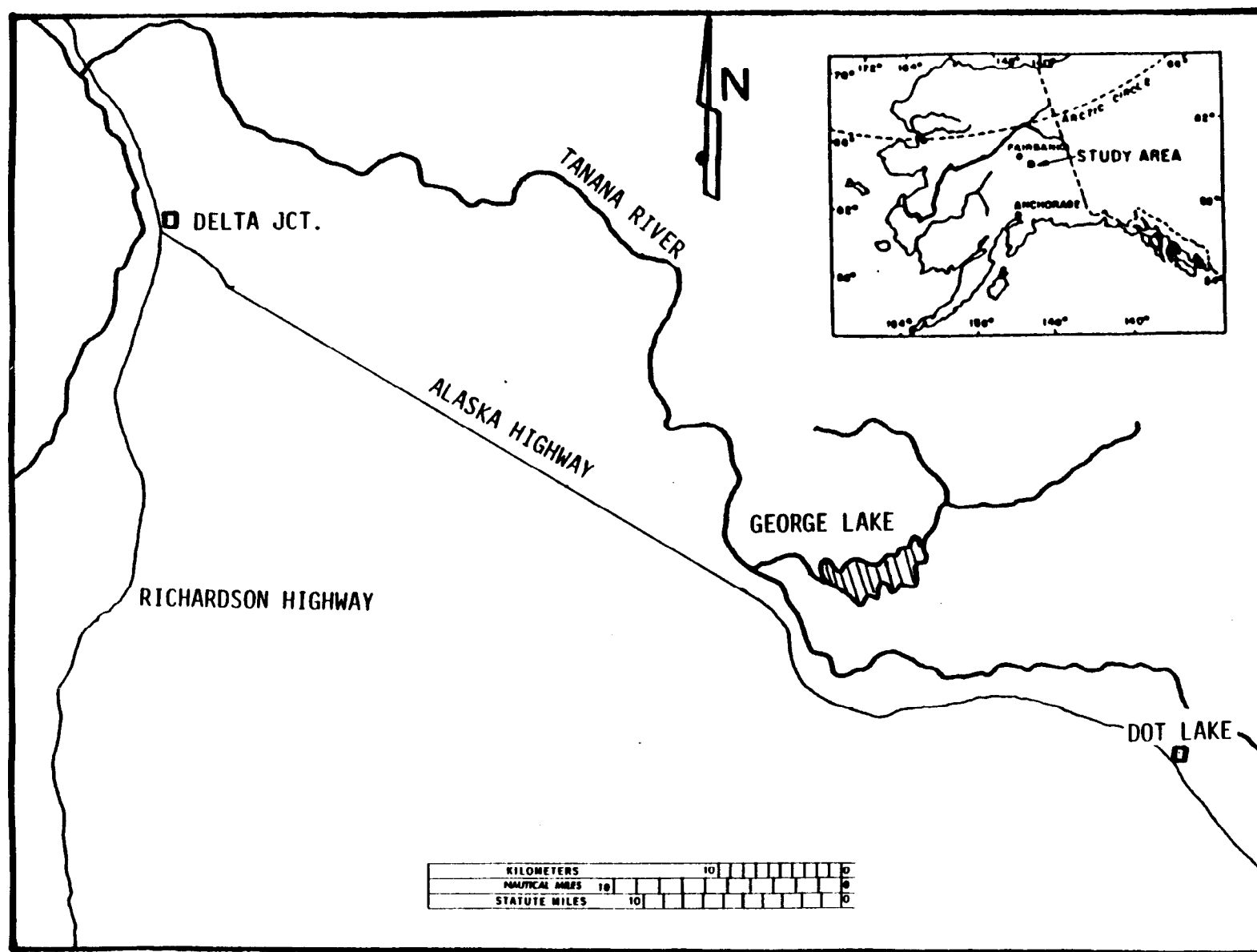


Figure 1. Location of George Lake, Alaska.

Fishing pressure in George Lake is moderate, ranging from 0.5 to 1.1 angler days annually per hectare (0.5 to 1.1 AAD/ha). Annual fishing effort averaged 1,041 days from 1977 through 1983 (0.57 AAD/ha) and increased to an average of 1,446 days (0.79 AAD/ha) from 1984 through 1986 (Table 1). Recently, fishing effort has increased substantially, particularly in 1986, when 1,321 anglers during 1,091 trips spent 1,957 days fishing (1.07 AAD/ha) in George Lake (Table 1).

Anglers at George Lake target on northern pike (Table 1), although other fish species are present, including Arctic grayling, burbot *Lota lota*, humpback whitefish *Coregonus pidschian*, least cisco *Coregonus sardinella*, round whitefish *Prosopium cylindraceum*, longnose suckers *Catostomus catostomus*, and slimy sculpin *Cottus cognatus*. Arctic grayling and round whitefish are only occasionally captured in the lake by anglers and by test netting during research surveys. Burbot abundance is also relatively low (Parker, Potterville, and Bernard 1988). Annual harvest of northern pike by recreational fishermen averaged 1,604 fish (0.88 per ha) from 1977 through 1983 and averaged 2,482 fish (1.36 per ha) from 1984 through 1986 (Table 1). The most recent (1986) harvest estimate of 3,076 northern pike (1.69 per ha) in George Lake represents the largest annual harvest of northern pike documented for this lake (Table 1).

#### Study Objectives and Report Goal

The goal of this on-going research program is the stock assessment of northern pike in George Lake and the investigation of the biology of this population relevant to management of sport fisheries in interior Alaska. Although this program began in 1986, initial efforts centered on identification of non-lethal, efficient sampling gear for the capture of northern pike. Seines proved to be an effective capture gear for study of northern pike (Peckham and Bernard 1987). During the work in 1986, ancillary information was collected concerning the life history of northern pike in George Lake including information on sex, length, weight, and age composition of the population, and these data complemented earlier information.

Specific objectives of the 1987 research program were:

- 1) to estimate abundance of northern pike in George Lake;
- 2) to estimate the sex composition of this population; and,
- 3) to estimate the parameters of the length-at-age relationship for this stock of northern pike.

Because other statistics, such as length frequency and age composition, were obtained in the 1987 study, these ancillary results are presented in this report. Also, because much of the life history information collected sporadically from 1972 through 1986 have not been reported, this report provides a forum for reporting that information. Thus, this report is intended to summarize all significant information available at the time of writing concerning the northern pike population in George Lake.

Table 1. Annual recreational fishing effort and harvest of sport fish from George Lake, 1977 through 1986<sup>1</sup>.

Year	Fishing effort			Harvest by species			
	Anglers	Trips	Fishing Days	White-fish	Grayling	Burbot	Northern Pike
1977			854	12	0	5	1,227
1978			1,271	0	27	0	1,392
1979			903	9	9	64	2,018
1980			1,057	0	17	0	1,395
1981			1,351	0	6	68	2,236
1982			989	0	0	31	1,635
1983			860	0	0	105	1,322
1984	557	523	1,254	65	65	143	1,700
1985	811	844	1,127	70	0	105	2,670
1986	1,321	1,091	1,957	0	134	32	3,076
Averages							
1977-83			1,041	3	8	39	1,604
1984-86	896	819	1,446	45	66	93	2,482
All years	896	819	1,162	16	26	55	1,867

<sup>1</sup> Source: Mills (1979-1987).

## METHODS

Abundance of northern pike in George Lake in 1987 was estimated with mark-recapture experiments. Two discrete sampling events took place with a 13-day hiatus between events. Sampling was conducted with a beach seine set from a boat and retrieved by hand to the shore. The seine was 66 m long and 3 m deep with 25 mm square mesh. The seine had a bag in the center.

After northern pike were removed from the seine, they were measured to the nearest millimeter of fork length (FL). Each captured northern pike was examined for presence of sexual products (sampling took place during and shortly after spawning), or the external characteristics described by Casselman (1974) were used to identify sex. Northern pike were tagged with Floy FD-68 anchor tags, and a fin was clipped. After obtaining data from each fish, live northern pike were returned to the water. George Lake was divided into sampling sections (Figure 2), and section of release and recapture was recorded for each fish.

Scales, otolith bones, and cleithra bones were taken from all northern pike killed during sampling. Because preliminary analysis conducted prior to 1987 indicated that all three aging structures provided similar ages (Peckham and Bernard 1987), scales were taken from a sub-sample of live northern pike handled during the first 1987 sampling event. Scales were stored in coin envelopes and were later removed, cleaned, and mounted on gum cards. Gum cards were used to make scale impressions on 20 mil acetate using a Carver press at 60,000 kg/cm<sup>2</sup> (20,000 psi) heated to 93°C for 30 seconds. Scale impressions were read along their dorsal radius on a Micron 770 Microfiche reader.

### Abundance Estimation

The Petersen method of estimating abundance through a mark-recapture experiment was discarded in favor of the stratified method of Darroch (1961) because marked fish failed to mix completely with unmarked fish and because there were unequal probabilities of capture in different areas of the lake. The hypothesis  $H_0: \theta_A = \theta_B$  (where  $\theta$  is the probability of recapturing a fish and A and B are the sections of the lake) was rejected ( $\chi^2 = 18.90$ ,  $df = 2$ ,  $P < 0.005$ , see Appendix Table 1). Since there was some movement of marked fish across the lake, mixing of these fish among the unmarked population was only partially completed by the second sampling event. The hypothesis  $H_0: \rho_A = \rho_B$  (where  $\rho$  is the probability of capture and A and B are the two sections of the lake) was rejected ( $\chi^2 = 3.39$ ,  $df = 1$ ,  $0.05 < P < 0.10$ , see Appendix Table 2). The probability of capture for northern pike had been higher in Section A during the first sampling event.

In situations of partial mixing and unequal probabilities of capture, the stratified method of Darroch (1961) will produce an unbiased estimate of abundance. The formula for this method is:

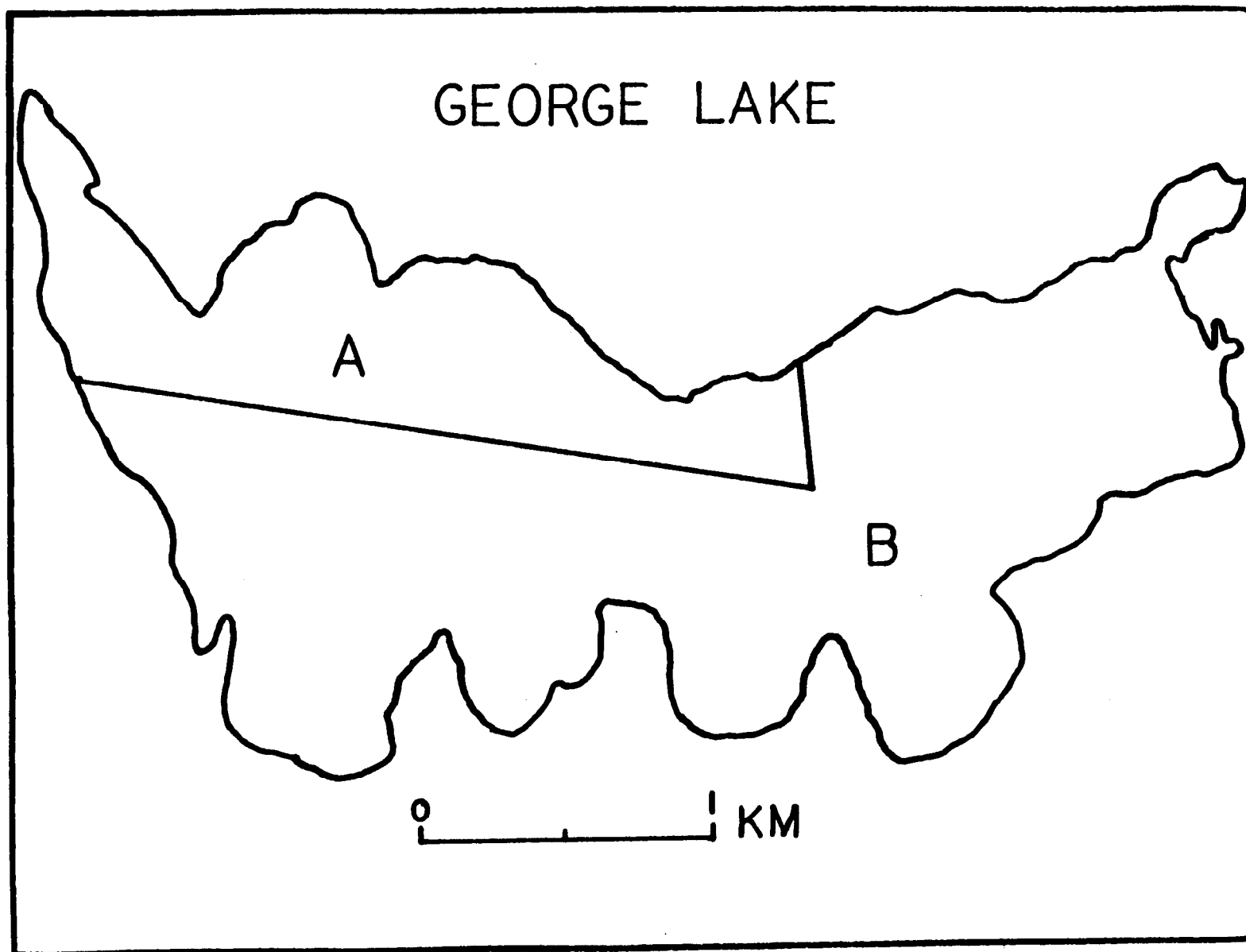


Figure 2. George Lake study sections.

$$(1) \quad \hat{N} = \mathbf{u}' \mathbf{M}^{-1} \mathbf{a} + n_1 ; \text{ where,}$$

$\hat{N}$  = estimate of abundance;

$\mathbf{u}$  = a vector whose elements  $\{u_j\}$  are the numbers of unmarked fish captured during the second sampling event in the  $j^{\text{th}}$  area of the lake;

$\mathbf{M}$  = a matrix whose elements  $\{m_{ij}\}$  are the number of marked fish released in the  $i^{\text{th}}$  area of the lake during the first sampling event and recaptured in the  $j^{\text{th}}$  area during the second sampling event;

$\mathbf{a}$  = a vector whose elements  $\{a_i\}$  are the numbers of marked fish released during the first sampling event in the  $i^{\text{th}}$  area of the lake; and,

$n_1$  = number of marked fish released during the first sampling event.

Because some recaptured fish lost their tags between sampling events, bootstrap methods of Efron (1982) were used to calculate the standard error of estimated abundance. Information on the sample of the  $n_2$  fish drawn during the second sampling event was placed in a  $n_2 \times 3$  matrix. Each row corresponded to the case history of an individual fish. The first column corresponded to the recapture history during the second sampling event (1 = a recaptured fish; 2 = a fish captured for the first time). The second column corresponded to the release history (0 = a fish that had been tagged and released during the first sampling event but had lost its tag; 1 = a fish that had been tagged then released into Area A; 2 = a fish that had been tagged then released into Area B). Numbers were assigned to fish captured for the first time during the second sampling event simply to fill out the matrix (these numbers were not used in calculations). The third column corresponded to the areas of capture (1 = captured in Area A; 2 = captured in Area B). A sample of  $n_2$  "fish" were drawn randomly from this matrix with replacement to obtain a bootstrap sample, the appropriate statistics were accumulated from this sample, and the Darroch method above was applied to these statistics. One hundred such bootstrap samples were drawn. In each sample, those "fish" that were recaptured in Area  $j$  but had lost their tags were assigned to elements of matrix "M" through Monte Carlo simulation based on the percentages of the tagged fish from Area  $j$  by area of release as follows:

FOR EACH "FISH":

Step 1: calculate a random number  $R$  ( $0 < R < 1$ );

Step 2:  $i \leftarrow 1$ ; and,

Step 3: is  $R < \left( \frac{\sum_{k=1}^i m_{kj}}{\sum_k m_{kj}} \right)$  ?



Yes: Assign this "fish to  $m_{ij}$ , then go to the next "fish".  
No:  $i \leftarrow i + 1$  then go to Step 3.

The average of the 100 bootstrap abundance estimates was used as the estimate of abundance of northern pike in George Lake and the standard deviation of the 100 bootstrap estimates was used as the standard error of estimated abundance.

### Composition Estimation

Because there was no evidence of size-selectivity for northern pike in the seines during the second sampling event, a single abundance estimate was calculated for all northern pike  $\geq 300$  mm FL. Goodness-of-fit tests showed that the population of recaptured fish had the same distribution of lengths as did the population of fish released during the first sampling event (Kolmogorov-Smirnov Two-Sample Test,  $P = 0.9994$ ). Also, the test of the hypothesis  $H_0: \rho_i = \rho$  (where  $\rho$  is the probability of capture and  $i$  corresponds to a 50-mm category for length) was not rejected ( $\chi^2 = 5.88$ ,  $df = 6$ ,  $0.25 < P < 0.50$ , see Appendix Table 3). However, a two-sample Kolmogorov-Smirnov test indicated that the first sample contained a greater portion of large fish than did the second sample ( $P < 0.005$ ). Because the second sample was demonstrably representative of the length distribution of the population, this difference between samples indicated the fish measured during the first sampling event were not representative.

The estimate of abundance was used in conjunction with various estimates of length, sex, and age composition to provide estimates of the numbers of northern pike in various categories:

- A) small (300 to 449 mm FL), medium-size (450 to 749 mm FL), and large fish (750 mm FL and longer);
- B) stock, quality, preferred, memorable, and trophy fish (Gablehouse 1984);
- C) males and females; and,
- D) age

The length distribution of all fish over 299 mm FL caught during the second sampling event was used to apportion the overall population estimate into three length classes to facilitate comparisons with other populations being studied in the Tanana River Drainage.

After review of Gablehouse (1984), categories for estimates of relative stock density were defined as follows: Stock size, 300 to 524 mm FL; Quality size, 525 to 654 mm FL; Preferred size, 655 to 859 mm FL; Memorable size, 860 to 1,079 mm FL; and Trophy size, 1,080 mm FL and longer. Relative stock density estimates were calculated as the percent of all northern pike 300 mm FL and longer within a defined category. The length distribution of the second sample was used to calculate relative stock densities.

Although the abundance of northern pike in George Lake was not estimated in 1986, the sex ratio of the population was determined from 204 northern pike (all > 299 mm FL) sampled that year. Because most of these fish were caught in gear that are not size-selective (seines and fyke nets), this sample was presumed to be representative of the population. Because subsequent analysis (reported later) showed female northern pike to be larger than males of the same age, and because the first 1987 sample is biased, only the second sample was used to calculate sex ratios of northern pike in 1987.

Because only a portion of the northern pike captured during the first sampling event were sampled for ages (scales), length composition of the aged sample was compared to length composition of the non-aged sample through the use of a chi-square test. Significant differences were found; larger northern pike were sampled at a significantly higher rate than were smaller fish. Next, a series of chi-square tests were used to select optimal length classes for stratification wherein variability within length classes was minimized and variation among length classes was maximized. Five length classes (300 to 549 mm; 550 to 599 mm; 600 to 649 mm; 650 to 699 mm; and 700 mm and larger) were ultimately selected meeting these criteria ( $\chi^2 = 140.79$ ,  $df = 4$ ,  $P < 0.005$ , see Appendix Table 4). Subsequently, age composition of the northern pike population within each of these five discrete length classes was estimated. The fraction by age in the population was estimated as the sum of the products of fractions by age by length class from the first sample and fractions by length class from the second sample as follows:

$$(2) \quad \hat{p}_i = \sum_y \hat{\theta}_y \hat{\phi}_y;$$

where:  $\hat{p}_i$  = estimated unbiased proportion of the population larger than 299 mm FL that are age  $i$ ;

$\hat{\theta}_y$  = estimated proportion of length class  $y$  from the first sample that is of age  $i$  ( $\sum_i \hat{\theta}_y = 1$ ); and,

$\hat{\phi}_y$  = estimated proportion of the population that are in length class  $y$  (calculated from the second sample).

Abundance of northern pike in various length, sex, and age categories was estimated as follows:

$$(3) \quad \hat{N}_i = \hat{p}_i(\hat{N});$$

where:  $\hat{N}_i$  = estimated number of northern pike 300 mm FL and longer in category  $i$ ;

$\hat{p}_i$  = estimated proportion of northern pike 300 mm FL and longer in category  $i$ ; and,

$\hat{N}$  = estimated abundance of all northern pike 300 mm FL and longer from Equation 1 above.

Variances for Equation 3 are from Goodman (1960):

$$(4) \quad V[\hat{N}_i] = (\hat{p}_i^2 V[\hat{N}]) + (\hat{N}^2 V[\hat{p}_i]) - (V[\hat{p}_i] V[\hat{N}]);$$

where:

$$(5) \quad V[\hat{p}_i] = \frac{\hat{p}_i(1-\hat{p}_i)}{n-1}; \text{ and,}$$

$n$  = number of northern pike sampled.

The lone exception to equation 4 occurred in calculation of age composition. Because of problems with covariances in equation 2, bootstrap techniques from Efron (1982) were used to estimate the variances in this situation.

#### Length-Weight Relationship Estimation

The two parameters of the length-weight relationship for northern pike in George Lake were estimated iteratively fitting the allometric model to the data with a computer program of the Marquardt algorithm. Parameters were estimated separately for data collected from 1972 to 1981 and for data collected in 1986. The parameters were estimated using a search over a set of starting values ( $a$ : 2 to 10 by 2 and  $b$ : 2.0 to 4.0 by 0.2). The set of estimates with the lowest least squares was selected as the best fit for the data set. Peckham and Bernard (1987) summarized these data and methods and the information is reported in this paper to provide a more complete description of the life history of northern pike in George Lake.

#### Length-at-Age Relationship Estimation

Mean length-at-age was calculated as the arithmetic mean length at each age for males, females, and all fish for each year in which sampling took place since 1972. Variances, standard errors, and 95% confidence intervals for these mean length-at-age estimates were calculated in standard fashion using normal distribution theory. Yearly mean length-at-age estimates with 95% confidence intervals and the across years weighted mean length-at-age for 3, 4, 5, 6, 7, and 8 year old northern pike were plotted to show trends in mean length-at-age for this population from 1972 through 1987.

Parameters of the von Bertalanffy growth equation for male and female northern pike were estimated through the Marquardt algorithm from data collected in 1987. Parameters were estimated 170 times, and each time, the algorithm began with a new set of initial parameter estimates. Initial values were as follows:  $a(L_\infty)$ : 0.2 to 1.2 by 2;  $b(K)$ : 0.0 to 0.4 by 0.1; and  $c(t_0)$ : -2.0 to 2.0 by 0.5. The set of estimates with the lowest least squares was selected

as the best fit for that sex. Male and female von Bertalanffy equations based upon 1987 data were compared through the use of Hotelling's  $T^2$  test (Bernard 1981).

#### Growth Rate Estimation

Annual growth rates of male and female northern pike were calculated as the difference in mean length of northern pike by sex at age  $i$  and at age  $(i + 1)$  and as the difference in mean length of individually tagged northern pike caught during both 1986 and 1987.

Because the sex of few fish sampled from 1972 through 1986 was determined (Appendix Tables 4 - 14), mean length at age for both sexes combined were estimated for northern pike sampled during these years.

### RESULTS

Of the 2,909 northern pike caught at least once during 1987, 2,880 were released and assumed alive at the completion of the study (17 were fish first tagged in 1986, then recaptured in 1987, and subsequently released in 1987; 2,275 were fish first tagged in 1987; and 588 were fish released without tags). Total sampling mortality during the 1987 study was 29 northern pike (1.0% of the fish caught at least once).

During the first sampling event (2 - 9 June 1987), 2,199 northern pike were caught (2,061 fish were tagged and released, 117 fish were released without being tagged, and 21 fish died during sampling). Thirteen of the 2,061 fish caught, marked, and released during the first sampling event were tagged and released in 1986. In 1986, 279 northern pike were tagged and released (65% caught in seines, 25% caught in fyke nets, and 10% caught in gill nets).

During the second sampling event (23 - 29 June 1987), 793 northern pike were caught (87 were recaptured fish, 228 fish were tagged and released for the first time, 471 fish were released without being tagged, and 8 fish died during sampling including 1 recaptured fish from the first sampling event). Of the 87 recaptured northern pike caught during the second sampling event, 4 were fish released during 1986 (3 tagged fish and 1 fish that had lost its tag) and 83 were fish marked and released during the first sampling event (78 tagged fish including 1 mortality and 5 fish that had lost their tags). Fish that had lost their tags were retagged during the second sampling event. Tag loss for fish tagged during 1986 was estimated to be 5.9% (1 tag loss of 17 recaptured northern pike). Tag loss for fish tagged during the first sampling event in 1987 was estimated to be 6.0% (5 tag losses of 83 recaptured northern pike).

#### Abundance

Estimated abundance of northern pike over 299 mm FL in George Lake in June 1987 was 17,662 (standard error = 2,105 fish). In 1987, 1,051 fish were released into "Area A" and 1,010 fish were released into "Area B" of George Lake (Figure 2) during the first sampling event. During the second sampling

event, 744 northern pike over 299 mm FL, including 83 recaptured fish, were caught. One hundred two northern pike were captured in "Area A" during the second event, including 17 recaptured fish (14 of these fish had been released in "Area A", 2 in "Area B", and 1 had lost its tag). Six hundred forty-one northern pike were captured in "Area B" during the second event, including 62 recaptured fish (19 of these fish were released in "Area A", 43 in "Area B" and 4 had lost their tags).

The northern pike population in George Lake was composed of an estimated 9,167 small fish (51.9%), 8,195 medium-size fish (46.4%), and 300 large fish (1.7%) (Table 2). Combined abundance of northern pike 450 mm FL and larger was 8,495 fish (standard error = 1,086 fish). The density of northern pike 300 mm FL and longer was estimated to be 9.69 fish per hectare, and the density of medium-size and large fish combined was estimated to be 4.66 fish per hectare.

#### Sex Ratios and Population Composition by Sex

Estimated abundance of females was higher than estimated abundance of males by about 1,000 fish (Table 3). Small males outnumbered small females by about 50% (estimated abundance: 5,546 males and 3,621 females). Medium-size females outnumbered males of the same size by about two fold (estimated abundance: 2,794 males and 5,401 females). Only females were found in the large fish category. The pattern in sex composition that was observed in 1987 is similar to the pattern observed in 1986 (Table 3).

#### Length Frequency

Modal lengths of male and female northern pike sampled during 1987 differed by 75 to 150 mm FL (Table 4 and Figure 3). Males were more abundant in the eight length classes from 300 to 499 mm FL, with those eight length classes each representing about 10% of the total sample. Females were more abundant in the 475 to 499 mm FL class. The 175 northern pike that could not or were not sexed were measured. These fish were included in the "all northern pike" category shown in Figure 3 (along with males and females).

Relative stock density estimates for 1986 and 1987 were similar (Table 5). No "trophy" size northern pike were caught in either year. The proportions of "memorable" and "preferred" northern pike decreased from 1986 to 1987 with the 1986 estimates being 0.28% and 8.29%, respectively, and the 1987 estimates being 0.00% and 4.72%, respectively (Table 5). The proportion of "quality" fish decreased slightly from 1986 to 1987 with the 1986 estimate being 22.10% and the 1987 estimate being 20.94% (Table 5). The proportion of "stock" size northern pike increased from 1986 to 1987, going from 69.33% to 74.34% (Table 5). There were 16 "stock size" and 4 "quality size" northern pike for every "preferred size" northern pike in George Lake during 1987.

#### Length-Weight Relationship

Peckham and Bernard (1987) estimated the parameters of the length-weight relationship from data on 356 fish sampled from 1972 to 1981 as:  $a = 6.27176$ ;  $SE(a) = 0.13990$ ;  $b = 2.8999$ ;  $SE(b) = 0.05273$ ; correlation (a,b) = 0.8335. They found that northern pike were more robust in 1986 than they had been

Table 2. Estimated abundance of small, medium-size, and large northern pike in George Lake during June 1987<sup>1</sup>.

Length Class (mm FL)	Number of northern pike caught during event(s)			Estimated Proportion <sup>2</sup>	SE	Estimated Abundance	SE
	First	Second	Both				
300-449	759	343	1,102	0.51891	0.01945	9,167	978
450-749	1,324	306	1,630	0.46293	0.01941	8,195	1,031
Over 749	49	12	61	0.01815	0.00520	300	342
Total over 300 mm	2,132	661	2,793	1.00000		17,662 <sup>3</sup>	2,105

<sup>1</sup> Small fish = 300-449 mm FL; medium-size fish = 450-749 mm FL; and, large fish = 750 mm FL and longer.

<sup>2</sup> Estimated abundance within length class calculated by multiplying the proportion of fish caught during the second sampling event within that length class by the overall population estimate of 17,662 fish.

<sup>3</sup> Estimated number of medium-size and large fish = 8,495 (S.E. = 1,086).

Table 3. Sex composition of northern pike in George Lake during 1986 and 1987.

Category	Northern Pike by FL Class (mm)				
	Small 300-449	Medium 450-749	Large Over 749	All Fish Over 299	All Fish Over 449
<u>1986 Sample</u>					
Sample Size	147	198	6	351	204
Number of Females	67	151	6	224	157
Number of Males	80	47	0	127	47
Female to Male Ratio	1:1.19	1:0.31	1:0.00	1:0.57	1:0.30
Percent Females	45.6	76.3	100.0	63.8	77.0
SE of % Females	4.1	3.0	0.0	2.6	3.0
Percent Males	54.4	23.7	0.0	36.2	23.0
SE of % Males	4.1	3.0	0.0	2.6	3.0
<u>1987 Population</u>					
Sample Size	304	293	10	607	303
Number of Females	120	193	10	323	203
Number of Males	184	100	0	284	100
Female to Male Ratio	1:1.53	1:0.52	1:0.00	1:0.88	1:0.49
Total Abundance	9,167	8,195	300	17,662	8,495
Percent Females	39.5	65.9	100.0	53.2	67.1
SE of % Females	2.8	2.8	0.0	2.0	2.7
Abundance of Females	3,621	5,401	300	9,322	5,701
SE(Abun. of Females)	398	695	342	870	775
Percent Males	60.5	34.1	0.0	46.8	32.9
SE of % Males	2.8	2.8	0.0	2.0	2.7
Abundance of Males	5,546	2,794	0	8,340	2,794
SE(Abun. of Males)	645	417	0	768	417

Table 4. Length frequency of northern pike in George Lake during the second sampling event in 1987.

Length Class (mm FL)	Males		Females		All Fish	
	Number	Percent	Number	Percent	Number	Percent
250-274	1	0.34	0		9	1.14
275-299	6	2.06	3	0.92	40	5.05
300-324	29	9.97	10	3.07	60	7.58
325-349	37	12.71	26	7.98	72	9.09
350-374	25	8.59	16	4.91	46	5.81
375-399	26	8.93	23	7.06	59	7.45
400-424	37	12.71	26	7.98	72	9.09
425-449	30	10.31	19	5.83	60	7.58
450-474	22	7.56	23	7.06	60	7.58
475-499	24	8.25	34	10.43	69	8.71
500-524	18	6.19	24	7.36	57	7.20
525-549	13	4.47	25	7.67	44	5.56
550-574	11	3.78	20	6.13	35	4.42
575-599	4	1.37	20	6.13	33	4.17
600-624	6	2.06	13	3.99	21	2.65
625-649	1	0.34	11	3.37	15	1.89
650-674	0		11	3.37	13	1.64
675-699	1	0.34	6	1.84	7	0.88
700-724	0		3	0.92	4	0.51
725-749	0		3	0.92	3	0.38
750-774	0		4	1.23	5	0.63
775-799	0		3	0.92	5	0.63
800-824	0		1	0.31	1	0.13
825-849	0		1	0.31	1	0.13
850-874	0		1	0.31	1	0.13
Totals	1,297	100.0	1,287	100.00	2,908	100.00



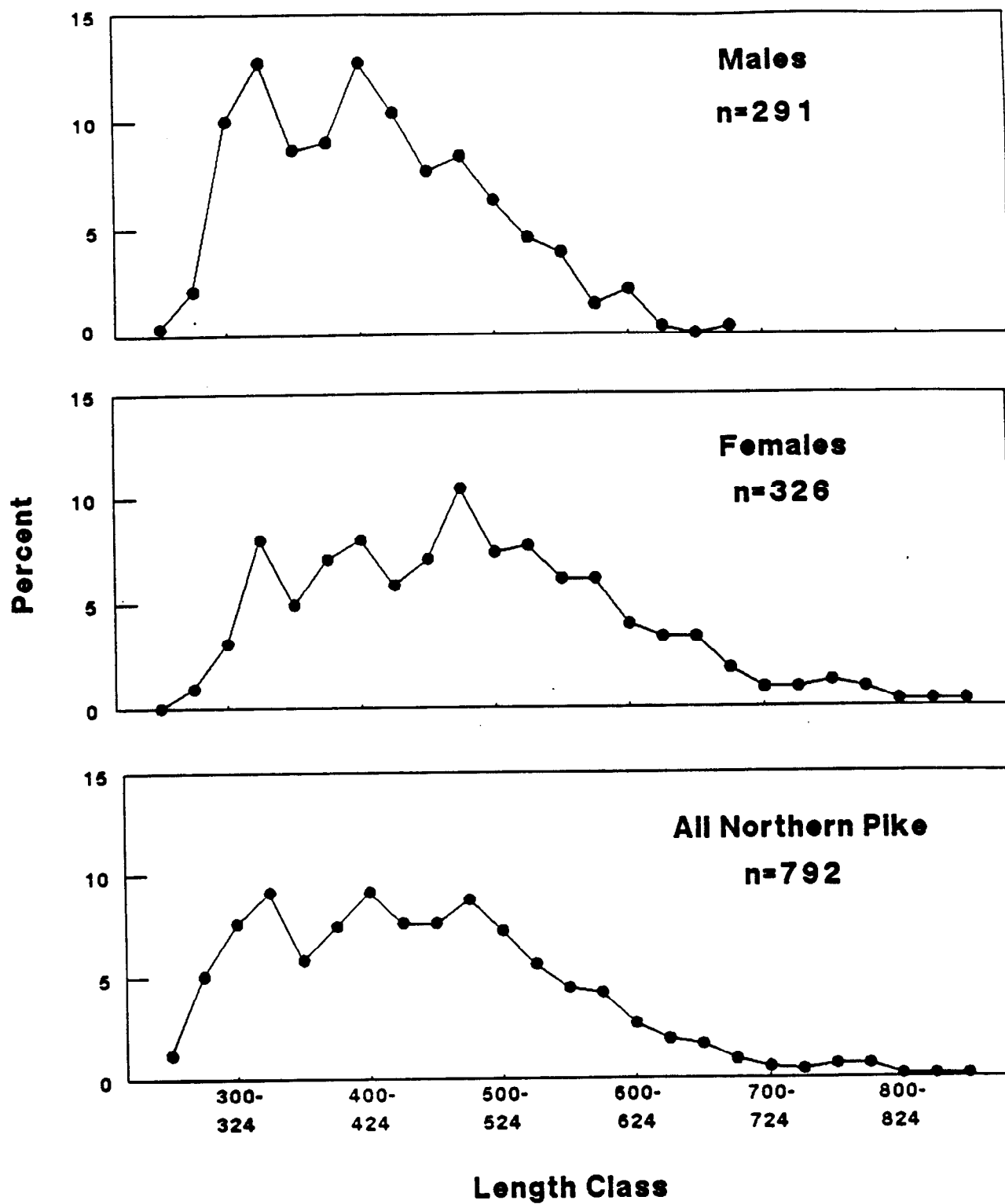


Figure 3. Length-frequency of northern pike in George Lake in 1987.

Table 5. Relative stock density estimates of northern pike sampled in George Lake in 1986 and 1987 with abundance estimates of stock, quality, preferred, memorable, and trophy size fish during 1987.

Category	Gablehouse <sup>1</sup> Minimum Length	1986 Data		1987 Data			
		Relative Stock Density <sup>1</sup>	SE	Relative Stock Density <sup>1</sup>	SE	Abund.	SE
Stock	300 mm FL	69.33	2.43	74.34	1.63	13,130	1,579
Quality	525 mm FL	22.10	2.18	20.94	1.52	3,699	443
Preferred	655 mm FL	8.29	1.45	4.72	0.79	833	98
Memorable	860 mm FL	0.28	0.28	0.00	0.00	02	0
Trophy	1,080 mm FL	0.00	0.00	0.00	0.00	0	0
Totals		100.00		100.00		17,662	2,105

<sup>1</sup> Relative stock density expressed as a percentage; categories taken from Gablehouse (1984).

<sup>2</sup> Although no northern pike in this category were caught during the second sampling event, six were caught during the first event.

between 1972 and 1981. The estimated parameters of the length-weight relationship for the 276 fish sampled in 1986 were:  $a = 7.3904$ ;  $SE(a) = 0.12029$ ;  $b = 2.9689$ ;  $SE(b) = 0.03137$ ; correlation  $(a,b) = 0.9093$  (Figure 4).

#### Age Composition

Of the 847 northern pike (347 males, 400 females, and 101 not sexed) aged, more fish were age 5 or younger than were older. Of the males, 33.7% were age 4; of the females, 22.5% were age 5. The oldest male and the oldest female were 12 years old. The age 4 cohort was the most abundant (5,390 fish) and was probably the youngest cohort fully recruited into the population estimate (Table 6). Because mean length-at-age minus two standard deviations for age 2 and age 3 northern pike in 1987 (Table 7) was less than 300 mm FL, the estimated abundance of age 2 and 3 fish reported in Table 6 will represent only those in their respective cohorts above 299 mm FL. Estimated abundance of northern pike by cohort decreased as age increased from age 4 through age 12 (Table 6).

#### Length-at-Age Relationship

Because the two sets of parameters, one for males and one for females, proved to be statistically different ( $P < 0.01$ ), separate length-at-age relationships for male and female northern pike are reported (Figure 5). Female northern pike had larger asymptotic lengths and larger coefficients of growth. Since the estimated "hatching" length of males was larger than females, this analysis suffers to some extent from the lack of data on age 1 and age 2 male and female fish. Although mean length-at-age for 3, 4, 5, 6, 7, and 8 year old northern pike has varied somewhat between 1972 and 1987 in George Lake, no consistent trends are apparent, and the 1987 length-at-age mean for each age class fall within the range of means observed for other years (Figure 6 and Appendix Tables 5 through 15).

#### Growth Rate

Differences in mean length among age groups in 1987 averaged 33 and 45 mm FL for males and females, respectively (Table 8); differences for sexes combined averaged 41 mm FL. The annual growth of individual northern pike tagged in 1986 and recaptured in 1987 averaged 53 mm FL for males, 54 mm FL for females, and 53 mm FL for sexes combined (Table 9). The difference in mean length and the annual growth were about the same regardless of the age or size of the fish.

### DISCUSSION

Estimated density of northern pike in George Lake (9.69 fish over 299 mm FL and 4.66 fish over 449 mm FL) was in the center of the range of densities estimated for other Alaskan populations. Density of northern pike over 449 mm FL in Volkmar Lake, Alaska, was estimated at 14.7 fish per hectare both in 1985 and in 1986 (Peckham 1986; Peckham and Bernard 1987). The density of northern pike over 299 mm FL in Volkmar Lake in 1987 was estimated to be 25.6 fish per hectare (Clark and Gregory 1988). The density of northern pike over

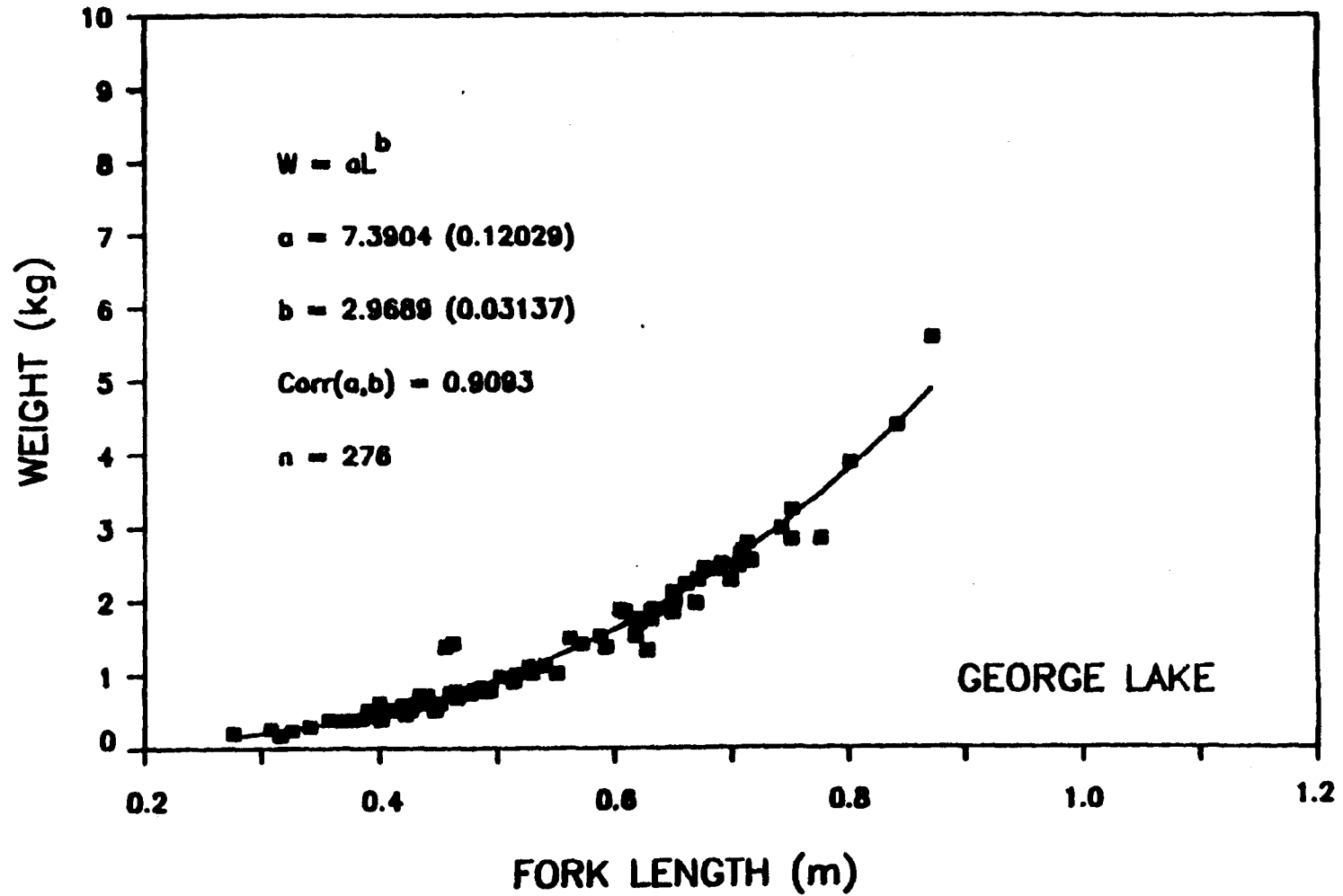


Figure 4. Length-weight relationship for George Lake northern pike sampled in 1986 (standard errors of parameter estimates are in parenthesis).

Table 6. Estimated age composition and estimated abundance by age cohort for northern pike larger than 299 mm FL in George Lake in 1987 (based on bootstrap sampling<sup>1</sup>).

Age Class	Estimated Proportion	Estimated Standard Error of Proportion	Estimated Abundance	Estimated Standard Error of Abundance
2 <sup>2</sup>	0.0251	0.0062	444	122
3 <sup>2</sup>	0.2423	0.0161	4,280	583
4	0.3052	0.0154	5,390	697
5	0.2325	0.0138	4,106	546
6	0.1042	0.0105	1,841	286
7	0.0400	0.0066	706	143
8	0.0205	0.0036	362	76
9	0.0209	0.0045	370	90
10	0.0072	0.0021	128	40
11	0.0008	0.0006	14	11
12	0.0012	0.0007	21	13
Totals	1.0000		17,662	2,105

<sup>1</sup> Bootstrap samples (100) were drawn from age and length data from 847 fish sampled during 2-9 June 1987, and of length data from 721 fish sampled during 23-29 June 1987. Means and standard errors for each proportion were calculated according to procedures in Efron (1982).

<sup>2</sup> These estimates are minima because mean lengths of two and three-year-old northern pike were 342 mm FL (SD = 42 mm) and 403 mm FL (SD = 58 mm), respectively.

Table 7. Mean length-at-age of northern pike sampled from George Lake in 1987.

Age	Males				Females				All			
	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE
2	5	392	1,101	15	3	320	194	8	17	342	1,728	10
3	97	397	2,275	5	45	412	4,292	10	164	403	3,349	5
4	117	448	3,452	5	74	489	3,568	7	212	465	3,857	4
5	68	496	3,056	7	90	531	5,205	8	184	518	4,776	5
6	34	544	3,065	9	60	604	4,413	9	103	578	5,490	7
7	13	557	4,831	19	37	663	4,438	11	55	632	6,432	11
8	9	614	2,612	17	30	725	5,816	14	42	695	7,158	13
9	2	607	1,849	30	35	734	5,287	12	43	703	10,802	16
10					23	770	6,084	16	23	770	6,084	16
11	1	676			1	709			2	693	272	12
12	1	724			2	774	9,216	68	3	757	6,700	47
All	347				400				848			

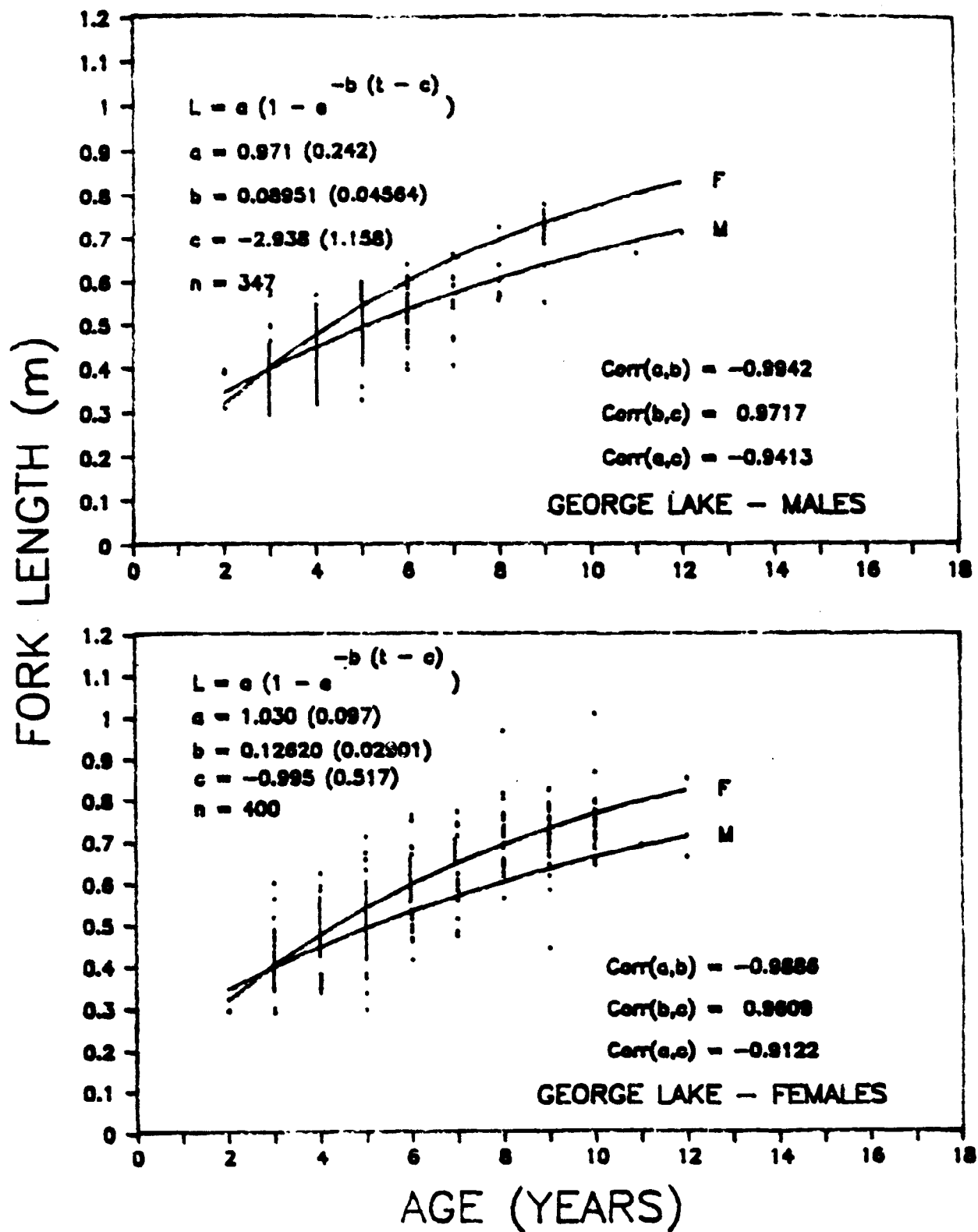


Figure 5. Length-at-age relationships for male and female northern pike sampled in 1987 (standard errors of parameter estimates are in parenthesis).

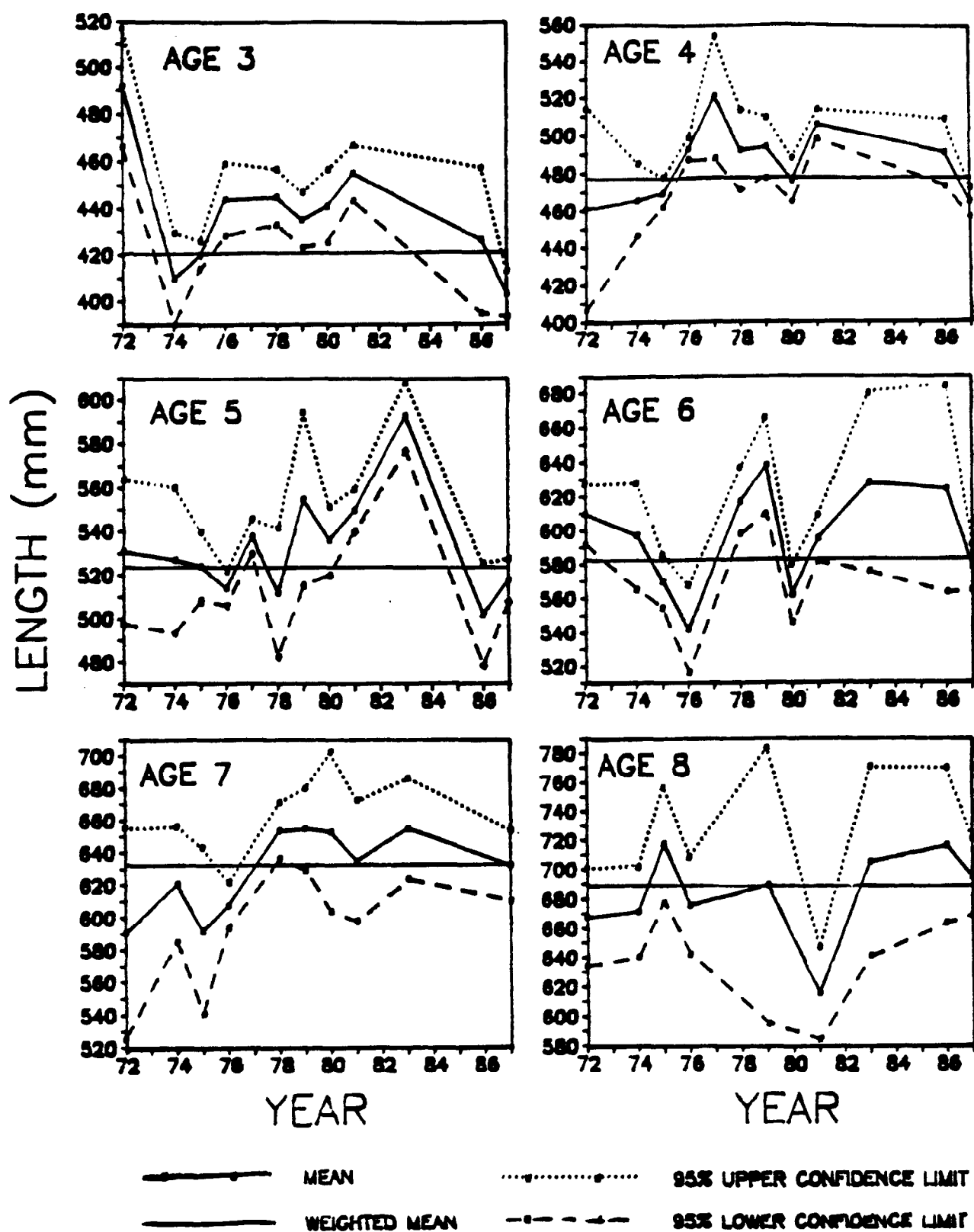


Figure 6. Mean length-at-age, 95% confidence intervals, and weighted means (across years) for 3, 4, 5, 6, 7, and 8 year old northern pike sampled from George Lake, 1972 through 1987.



Table 8. Growth rates (mm FL) of northern pike in George Lake determined from length-at-age analysis of the 1987 sample.

Age	Males		Females		All Fish	
	Mean Length	Length Change	Mean Length	Length Change	Mean Length	Length Change
2	392	5	320	92	342	61
3	397	51	412	77	403	62
4	448	48	489	42	465	53
5	496	48	531	73	518	60
6	544	13	604	59	578	54
7	557	57	663	62	632	63
8	614	-7	725	9	695	8
9	607	35 <sup>1</sup>	734	36	703	67
10		34 <sup>1</sup>	770	-61	770	-77
11	676	48	709	65	693	64
12	724		774		757	
Averages		33.2		45.4		41.5

<sup>1</sup> Growth for males between age 9 and 11 was arbitrarily split into one half.

Table 9. Annual growth increments of individual northern pike tagged in George Lake in 1986 and recaptured in 1987.

Tag Number	Sex	Length in 1987 (mm FL)	Length in 1986 (mm FL)	Annual Increment of Growth (mm FL)
17,385	Male	398	391	7
3,870	Male	470	405	65
3,995	Male	440	425	15
3,778	Male	585	461	124
3,859	Male	Not Recorded	675	
3,965	Female	400	326	74
3,997	Female	473	392	81
3,991	Female	500	415	85
3,962	Female	522	433	89
3,835	Female	480	446	34
3,986	Female	510	450	60
3,926	Female	549	475	74
3,940	Female	579	520	59
3,822	Female	530	529	1
3,970	Female	550	573	-23
3,924	Female	687	632	55
Averages				
Males: (n = 4)				53
Females: (n = 11)				54
All Fish: (n = 15)				53

299 mm FL in T Lake during 1987 was estimated by Clark (1987) to be 3.85 fish per hectare. The density of northern pike over 449 mm FL in T Lake was estimated to be 2.80 and 3.19 fish per hectare in 1986 and 1987, respectively (Peckham and Bernard 1987; Clark 1987).

Estimated density of northern pike in George Lake was in the low to center of the range of densities reported in the scientific literature for various non-Alaskan populations. Average density of northern pike over 400 mm TL in Savanne Lake, Ontario, in 1973, 1977, and 1978 was estimated at 6.66 fish per hectare with a range of 5.91 to 7.19 fish per hectare (Mosindy and Momot 1987). Mann (1980) estimated average density of age 1 and older northern pike in the Stour River, England, to be 61 fish per hectare over a 5 year period (range 27 to 127 fish per hectare). Mann (1980) also reported a density range of 32 to 80 age 1 and older northern pike per hectare in the Frome River, England. Seaburg and Moyle (1964) estimated the density of northern pike over 250 mm TL in Grove Lake, Minnesota, at 7.6 fish per hectare, and the density of northern pike over 355 mm TL in Maple Lake, Minnesota, at 4.8 fish per hectare. Over a series of years, the density of northern pike over 356 mm TL in Murphy Flowage, Wisconsin, was estimated by Snow (1978) to range from 5.8 to 40.6 fish per hectare (mean = 20.8 fish per hectare). Kempinger and Carline (1978) estimated density of northern pike in Escanaba Lake, Wisconsin, over a series of years, and they reported a mean density of 6.9 fish per hectare for age 1 and above fish and a mean of 0.9 fish per hectare for fish over 560 mm TL.

Sex ratios skewed towards females in the older and larger sized portions of the population as found in George Lake is typical of northern pike populations in general. In Volkmar Lake in 1986, females represented 30.1%, 44.6%, and 86.0% of the fish in the small, medium, and large fish categories, respectively (Peckham and Bernard 1987). In T Lake, females represented 7.7%, 51.5%, and 100.0% of the fish in the small, medium, and large fish categories, respectively, in 1986, and 34.8%, 67.5%, and 100.0% of the fish in the small, medium size, and large fish categories in 1987 (Clark 1987). Carlander (1969) provides a review of studies conducted outside of Alaska.

Northern pike in George Lake are smaller, on the average, than northern pike in T or Volkmar Lakes. In 1987, male George Lake northern pike were most abundant in the 325 to 349 and the 400 to 424 mm FL classes; females were most abundant in the 475 to 499 mm FL class in 1987. In 1986, George Lake male northern pike were most abundant in the 400 to 449 mm FL class, whereas, females were most abundant in the 450 to 499 mm FL class (Peckham and Bernard 1987). Modal lengths of Volkmar Lake northern pike occurred at about 575 mm FL for both sexes in 1986 (Peckham and Bernard 1987). Length modes for T Lake northern pike occurred in the 600 to 649 mm FL class and the 450 to 499 mm FL class for males in 1986 and 1987, respectively. For females, length modes occurred in the 650 to 749 mm FL classes and the 650 to 699 mm FL class in 1986 and 1987, respectively (Clark 1987). "Stock" size fish represented about two thirds and three quarters of the population in George Lake in 1986 and 1987, respectively. "Quality" size fish represented one fifth of the population and larger fish representing only a few percent. In T Lake, "stock" size fish represented 13.4% and 39.8% of the 1986 and 1987 population, respectively, with the large increase of "stock" size fish in 1987 being the result

of recruitment (Clark 1987). "Quality" and "preferred" size fish represented 85.2% and 58.4% of the T Lake population in 1986 and 1987, respectively (Clark 1987). "Memorable" size fish in George Lake represented 0.28% and 0.08% of the population in 1986 and 1987, respectively, whereas, in T Lake they represented 1.4% and 1.8% of the population in 1986 and 1987, respectively (Clark 1987). The trend of smaller northern pike in George Lake as compared to Volkmar and T Lakes is likely due to lower exploitation rates by the respective sport fisheries in Volkmar and T Lakes as compared to a higher sport fishery exploitation rate in George Lake (see latter portion of the discussion section).

The oldest northern pike sampled from George Lake was about as old as those sampled in Volkmar (Peckham and Bernard 1987) and T Lakes (Clark 1987). For males, maximum ages were 11, 12, and 13 for T, George, and Volkmar Lakes, respectively. For females, maximum ages were 12, 14, and 16 for George, Volkmar, and T Lakes, respectively. The reason that the oldest northern pike have been found in T Lake is probably due to the lower exploitation rate by the sport fishery in T Lake (Clark 1987).

Length-at-age relationships for male and female northern pike in George Lake were significantly different, with females having the larger mean length-at-age. This same trend occurred in Volkmar Lake (Peckham and Bernard 1987) and in T Lake (Clark 1987), and the trend is typical of northern pike populations in the southern portion of their range (see Carlander 1969).

Although growth rates of George Lake northern pike were within the range of growth estimates documented for T Lake and Volkmar Lake northern pike populations, trends of decreasing growth commensurate with increasing fish size were not evident. Peckham and Bernard (1987) found that growth increments of northern pike in Volkmar Lake was inversely proportional to length of the fish. They documented annual average growth increments of 92 mm FL for small males (300 to 349 mm FL) and 14 mm FL for large males (700 to 749 mm FL) in Volkmar Lake. Small females (300 to 349 mm FL) in Volkmar Lake annually grew 107 mm FL and large females (800 to 949 mm FL) grew 22 mm FL. In T Lake, a similar trend occurred with small males (under 450 mm FL) growing 85 mm FL and large males (650 to 699 mm FL) growing 5 mm FL on an annual basis (Clark 1987). Annual growth of small females (under 450 mm FL) in T Lake averaged 70 mm and large females (over 750 mm FL) grew 4 mm.

The 1987 cohort abundance estimates for the George Lake northern pike population as reported in Table 6 are the first abundance estimates by age for an Alaskan northern pike population. With successive abundance estimates and apportionment of these estimates by cohort, age-specific mortality rates for the George Lake northern pike population can be developed in future years. These analyses will provide needed information for estimation of sustainable yield.

Sport fishing harvest of northern pike in George Lake between 1984 and 1986 ranged from 1,700 to 3,026 (average: 2,482) fish (Mills 1985-87). Exploitation rate by the George Lake sport fishery is probably somewhere between 14% and 23%, assuming the 1987 harvest will be about the same as the recent average and depending upon size of fish retained by anglers (if anglers retained

small fish, exploitation rate would be 14% of the estimated abundance of fish over 299 mm FL; if anglers only retained medium-size and large fish, exploitation rate would be 23% of the estimated abundance of fish over 449 mm FL). Probably, most anglers only keep northern pike over 449 mm FL (about 18 inches), but some anglers probably keep a few small fish as well. For comparison, the exploitation rate by the sport fishery for northern pike over 449 mm FL in T Lake in 1986 was about 10% (Clark 1987). The 1986 sport fishery harvest in Volkmar Lake was 657 northern pike (Mills 1987). Abundance of northern pike over 299 mm FL was 8,053 and abundance of northern pike over 449 mm FL was 4,026 during June 1986 (Peckham and Bernard 1987), resulting in a range of exploitation from 8% to 16% with the range dependent upon size of fish retained by anglers. Thus the northern pike population in George Lake suffers a higher level of exploitation than do the T Lake and Volkmar Lake northern pike populations.

Estimated exploitation rate of northern pike in Volkmar Lake (8% to 16%) appears to be sustainable because estimated abundance between 1985 and 1986 remained the same (Peckham 1986; Peckham and Bernard 1987). Recent exploitation rate of northern pike in Minto Flats was about 30% and this exploitation rate was judged as unsustainable by Holmes (1987). Based upon the large recruitment and the relatively low exploitation rate (10.7%) estimated between 1986 and 1987, Clark (1987) concluded that the minimum estimated harvest of 43 northern pike in T Lake represented a sustainable yield. Although definitive estimation of sustainable yield of the George Lake northern pike population will require additional information concerning population abundance, mortality rates, and recruitment rates obtained over a series of years, it seems doubtful that harvests of the magnitude of the 1986 harvest can be sustained. Considering the increasing harvest trends observed in recent years (1,700 in 1984, 2,670 in 1985, and 3,076 in 1986), it seems likely that sport fishery regulatory changes are needed to prevent overharvest and collapse of the northern pike population in George Lake. The daily bag and possession limit in the sport fishery of the Tanana Drainage was reduced from 12 to 5 northern pike by the Alaska Board of Fisheries in December 1987. It is uncertain if this recent change will be an adequate regulatory measure to insure that the harvest of northern pike in George Lake is sustainable in future years. It is recommended that abundance, mortality rates, and recruitment rates of the northern pike population in George Lake be monitored during the next few years through mark-recapture experiments to estimate sustainable yield and to study the effects of the sport fishery on the stock.

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## APPENDIX

Appendix Table 1. Numbers of northern pike tagged in each of two areas in George Lake 2 - 9 June and their location 23 - 29 June 1987.

Area of Release	Area of Recapture		Not Recaptured
	A	B	
Released in A	14	19	1,018
Released in B	2	43	965
$\chi^2 = 18.90^1$		$P < 0.005$	$DF = 2$

<sup>1</sup> The  $\chi^2$  value is the test statistic for the hypothesis of equal probability of recapturing fish in either half of George Lake (see Seber 1982).

Appendix Table 2. Numbers of tagged and untagged northern pike captured by area in George Lake 23 - 29 June 1987.

Category	Area	
	A	B
Recaptured Fish	16	62
New Fish	86	579
$\chi^2 = 3.39^1$ $0.05 < P < 0.010$ $DF = 1$		

<sup>1</sup> The  $\chi^2$  value is the test statistic for the hypothesis of equal probability of capturing tagged fish in either half of George Lake (see Seber 1982).

Appendix Table 3. Numbers of northern pike tagged by length class in George Lake 2 - 9 June then sampled 23 - 29 June 1987.

Length Class (mm FL)	Recaptured	Not Recaptured
300 - 349	6	127
350 - 399	9	249
400 - 449	12	329
450 - 499	19	361
500 - 549	19	362
550 - 599	12	251
Over 600	6	299
$\chi^2 = 5.88^1$ $0.25 < P < 0.5$ $DF = 6$		

<sup>1</sup> The  $\chi^2$  value is the test statistic for the hypothesis of equal probability of capturing fish across the seven length classes.

Appendix Table 4. Numbers of northern pike aged and not aged by length class in George Lake 2 - 9 June 1987.

Length Class (mm FL)	Aged	Not Aged
300 - 549	538	1,006
550 - 599	106	159
600 - 649	61	61
650 - 699	51	27
Over 700	91	13
<hr/>		
$\chi^2 = 140.79^1$	$P < 0.005$	DF = 4

<sup>1</sup> The  $\chi^2$  value is the test statistic for the hypothesis of equal probability of aging fish across the five length classes.

Appendix Table 5. Mean length-at-age of northern pike sampled from George Lake in 1972<sup>1</sup>.

Age	Males				Females				All			
	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE
0									1	138		
1	2	259	72	6					5	196	2,924	24
2	2	321	256	11					2	321	256	11
3	1	474			1	510			2	492	324	13
4	3	461	2,318	28					3	461	2,318	28
5	5	528	2,073	20	3	535	2,690	30	8	531	2,313	17
6	1	608			7	611	731	10	8	610	640	9
7	1	484			3	627	678	15	4	591	4,361	33
8	1	632			5	675	1,816	19	6	668	1,772	17
9					1	884			1	884		
10					1	810			1	810		
11					1	985			1	985		
All	16				22				42			

<sup>1</sup> Fish were captured with either 38 by 1.8 m variable mesh monofilament gill nets with five mesh sizes ranging from 6 to 64 mm, with a 15.3 by 3 m nylon bag seine with 6 mm mesh, or with hook and line gear. Sampling took place in August.



Appendix Table 6. Mean length-at-age of northern pike sampled from George Lake in 1974<sup>1</sup>.

Age	Males				Females				All			
	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE
0									1	129		
1												
2	1	308			1	288			4	319	977	10
3	5	433	222	7	3	382	790	16	17	410	1,773	10
4	7	460	2,521	19	4	467	1,197	17	26	466	2,536	10
5	1	451			2	518	6,972	59	12	527	3,651	17
6	2	513	961	22	4	609	1,107	17	19	597	4,812	16
7	1	599			2	679	272	12	10	621	3,171	18
8	2	611	2,970	39	5	677	2,903	24	12	672	3,246	16
9					7	674	926	11	14	698	2,596	14
10					2	730	1,640	29	3	704	2,534	29
11					1	650			2	731	6,561	57
12					1	812			1	812		
All	19				32				121			

<sup>1</sup> Fish were captured with either New Hampshire style fyke nets or with hook and line gear. Sampling took place in June, July, and August.

Appendix Table 7. Mean length-at-age of northern pike sampled from George Lake in 1975<sup>1</sup>.

Age	Males				Females				All			
	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE
1									1	180		
2									8	351	497	8
3	9	413	667	9					232	420	1,921	3
4	3	465	456	12					123	470	2,018	4
5	1	442							24	524	1,600	8
6									2	570	121	8
7	1	520							6	592	4,153	26
8									6	718	2,493	20
9	1	809							2	795	210	10
10									1	590		
11												
12												
13									1	799		
All	15								406			

<sup>1</sup> Fish were captured with either New Hampshire style fyke nets or with hook and line gear. Sampling took place in June.

Appendix Table 8. Mean length-at-age of northern pike sampled from George Lake in 1976<sup>1</sup>.

Age	Males				Females				All			
	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE
2									12	344	244	5
3									31	444	1,777	8
4									189	493	1,648	3
5									77	514	1,403	4
6									17	542	2,797	13
7									4	608	193	7
8									3	676	897	17
9									2	690	1,722	29
10									2	696	2,209	33
All									337			

<sup>1</sup> Fish were captured with either New Hampshire style fyke nets or with hook and line gear. Sampling took place in June, July, August, and September.

Appendix Table 9. Mean length-at-age of northern pike sampled from George Lake in 1977<sup>1</sup>.

Age	Males				Females				All			
	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE
3									1	495		
4									2	521	576	17
5									9	538	180	4
6									1	571		
7												
8												
9									1	800		
10									3	934	341	11
11												
12												
13									1	904		
All									18			

<sup>1</sup> Fish were captured with either 38 by 1.8 m variable mesh monofilament gill nets with five mesh sizes ranging from 6 to 64 mm, New Hampshire style fyke nets, or with hook and line gear. Sampling dates not recorded.

Appendix Table 10. Mean length-at-age of northern pike sampled from George Lake in 1978<sup>1</sup>.

Age	Males				Females				All			
	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE
2									24	369	1,460	8
3									43	445	1,726	6
4									19	492	2,464	11
5					1	597			8	512	1,908	15
6									14	617	1,481	10
7									9	654	756	9
8												
9									4	726	1,983	22
10									2	849	841	21
11					1	851			1	851		
12									1	870		
13					1	914			1	914		
All					3				126			

<sup>1</sup> Fish were captured with either 38 by 1.8 m variable mesh monofilament gill nets with five mesh sizes ranging from 6 to 64 mm, New Hampshire style fyke nets, or with hook and line gear. Sampling took place in June and July.

Appendix Table 11. Mean length-at-age of northern pike sampled from George Lake in 1979<sup>1</sup>.

Age	Males				Females				All			
	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE
1									1	215		
2					1	348			5	354	620	11
3					2	440	702	19	17	435	602	6
4	1	468							14	494	882	8
5					1	561			8	555	3,218	20
6	1	598							4	638	816	14
7	1	575			2	655	380	14	12	655	2,162	13
8	1	617							4	690	9,334	48
All	4				6				65			

<sup>1</sup> Fish were captured with either 38 by 1.8 m variable mesh monofilament gill nets with five mesh sizes ranging from 6 to 64 mm, New Hampshire style fyke nets, or with hook and line gear. Sampling dates not recorded.

Appendix Table 12. Mean length-at-age of northern pike sampled from George Lake in 1980<sup>1</sup>.

Age	Males				Females				All			
	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE
2									10	365	977	10
3	1	425							26	441	1,853	8
4	2	469	49	5	4	483	3,861	31	52	476	2,165	6
5	1	466			3	554	2,071	26	33	536	2,037	8
6	2	524	16	3	3	543	118	6	18	562	1,561	9
7					2	718	2,304	34	7	653	4,318	25
8												
9					2	787	2,209	33	2	787	2,209	33
10					1	844			1	844		
11									1	915		
12												
13												
14									1	915		
All	6				15				151			

<sup>1</sup> Fish were captured with either 38 by 1.8 m variable mesh monofilament gill nets with five mesh sizes ranging from 6 to 64 mm, various styles of fyke nets, or hook and line gear. Sampling took place in May, June, and August.

Appendix Table 13. Mean length-at-age of northern pike sampled from George Lake in 1981<sup>1</sup>.

Age	Males				Females				All			
	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE
2									5	355	387	9
3									28	455	981	6
4	2	491	210	10	3	504	468	12	32	506	526	4
5	3	532	718	15	3	578	1,105	19	35	550	994	5
6	1	570			3	627	774	16	31	595	1,509	7
7	1	530			4	652	881	15	10	635	3,739	19
8					1	638			2	616	484	16
9									3	795	367	11
10									1	772		
All	7				14				147			

<sup>1</sup> Fish were sampled with hook and line gear in May and July.



Appendix Table 14. Mean length-at-age of northern pike sampled from George Lake in 1983<sup>1</sup>.

Age	Males				Females				All			
	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE
2									1	320		
3												
4									1	582		
5									3	593	206	8
6									3	628	2,115	27
7									2	655	529	16
8									2	706	2,116	33
9									1	756		
All									13			

<sup>1</sup> Fish were sampled with hook and line gear in May, July, and August.

Appendix Table 15. Mean length-at-age of northern pike sampled from George Lake in 1986<sup>1</sup>.

Age	Males				Females				All			
	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE	Sample Size	Mean	Var.	SE
2	4	293	125	3	2	286	20	3	6	290	101	4
3	1	468			6	419	1,647	17	7	426	1,712	16
4	1	483			3	494	410	12	4	491	329	9
5	3	491	333	11	1	533			4	502	574	12
6					2	624	1,936	31	2	624	1,936	31
7												
8									3	717	2,249	27
All	9				14				26			

<sup>1</sup> Fish were captured with seines, trap nets, and variable mesh gill nets (see Peckham and Bernard 1987 for details concerning gear types). Sampling took place in June and August.